Argonne NATIONAL LABORATORY

... for a brighter future

U.S. Department of Energy

THE UNIVERSITY OF CHICAGO

Office of Science U.S. DEPARTMENT OF ENERGY

A U.S. Department of Energy laboratory managed by The University of Chicago

# Advanced Photon Source Update

*J. Murray Gibson*

*Director, Advanced Photon Source*

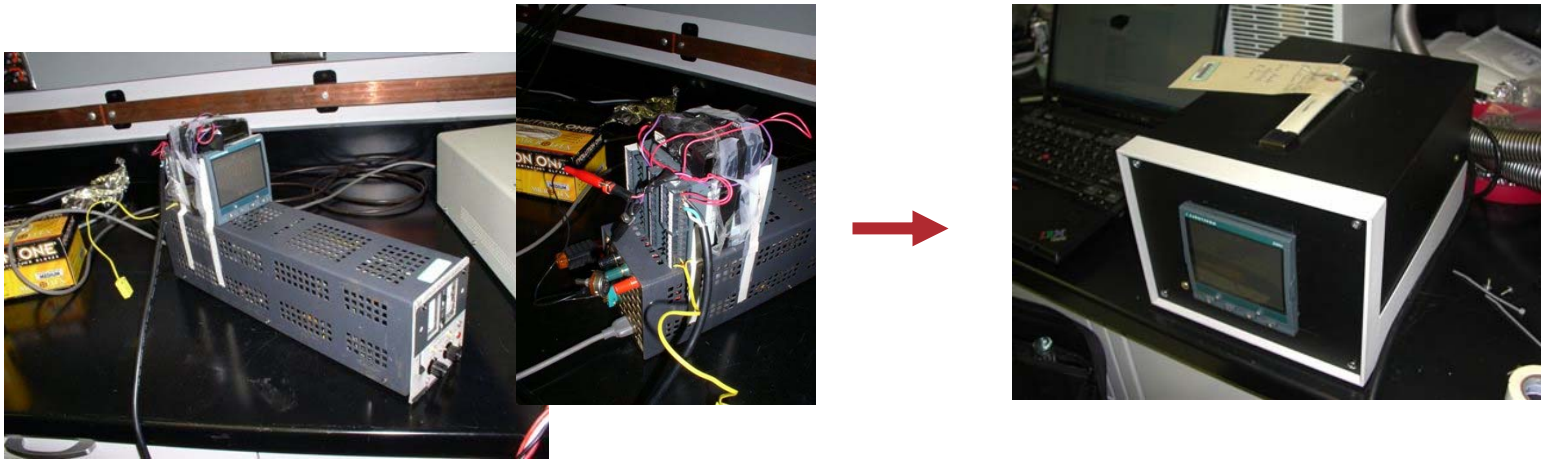
*Associate Laboratory Director, Scientific User Facilities*

*Presented at ANL Users' Week 2007*

*May 7th, 2007*

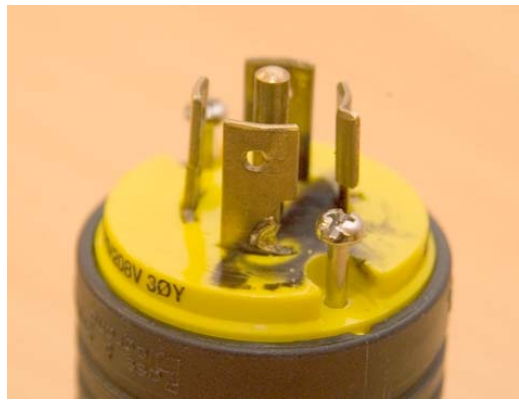
# *Safety is always first on our minds…*

- We now inspect all non-NRTL-approved user electrical equipment for improved safety



*H*rv*rd University Temperature Controller*

- Users must not carry out unauthorized electrical work!
  - This person could have been seriously hurt
  - He could easily have gotten help…



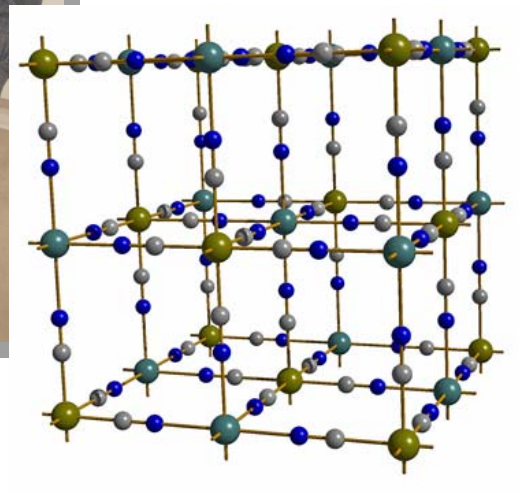
# *The legacy of Joe Smith...*

- Joe organized a multi-institutional, multi-disciplinary group of scientists to found the Consortium (now Center) for Advanced Radiation Sources (CARS) to use the Advanced Photon Source in their research, which now operates 4 sectors at APS
- Louis Block Professor Emeritus in Geophysical Sciences and the College at The University of Chicago
- Author of more than 400 scientific articles, *Geometrical and Structural Crystallography*, and three-volume scientific reference series on feldspar minerals
- Helped industry harness zeolites as molecular sieves to improve the yield of gasoline from oil and produce environmentally friendly, phosphate-free detergents
- Helped develop microprobe for precision x-ray analyses of experimental samples

Joseph Smith
1928-2007

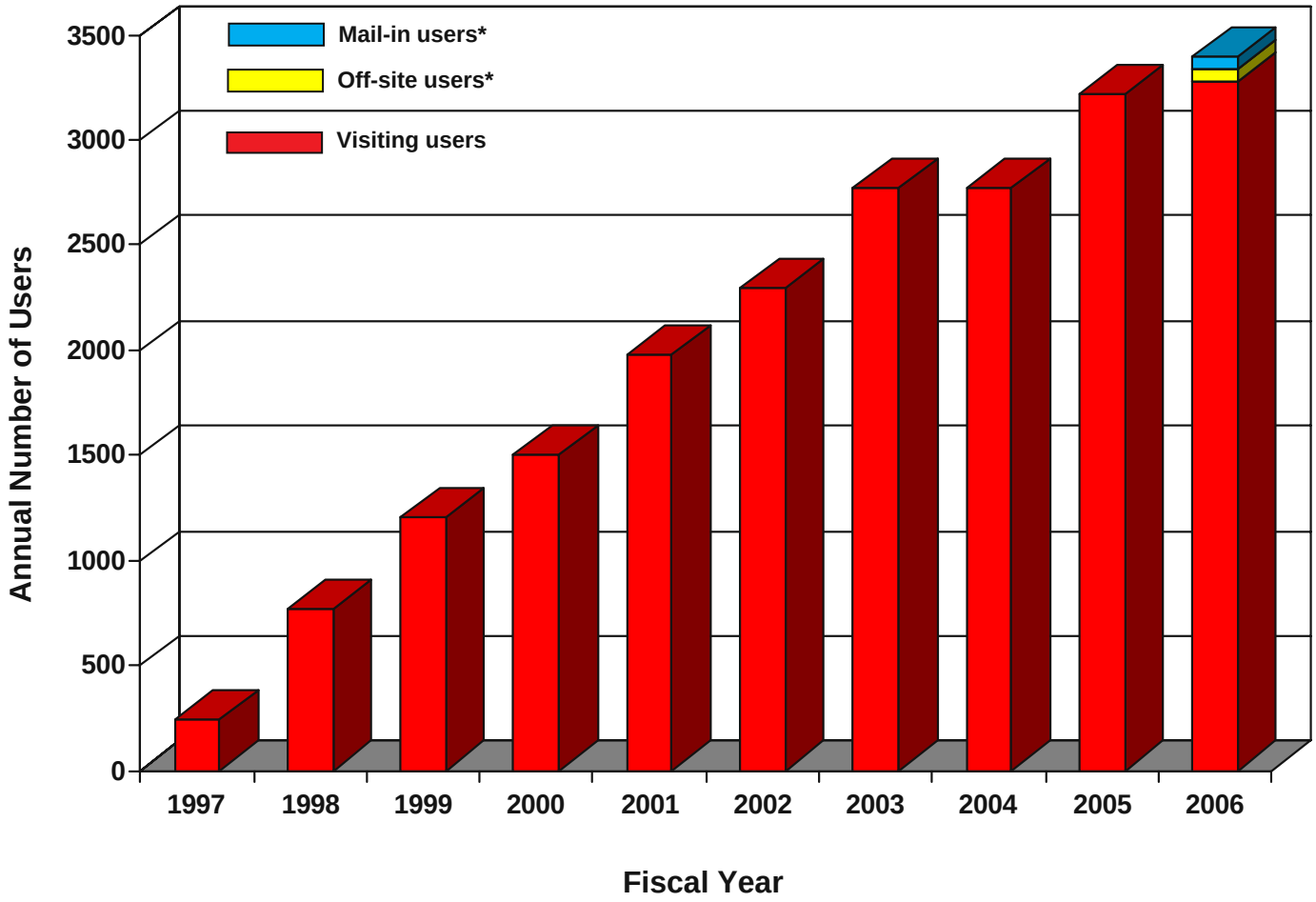
# *Innovation continues*
## *Peter Chupas receives 2006 Sidhu Award*

- Award given each year by Pittsburgh Diffraction Society “for best contribution to crystallography or diffraction by an investigator within five years of the Ph.D.”
- Chupas recognized for his work on studies leading to development of a new method for rapid collection of pair-distribution-function (PDF) data
- Now the method of choice for PDF measurements and forms basis of U.S.’s first and only dedicated pair-distribution-function beamline (11-ID-B at APS) where Peter is beamline scientist



*Pete stands on the shoulders of another giant, Jim Jorgenson, who passed away this year*

# Annual number of unique APS users

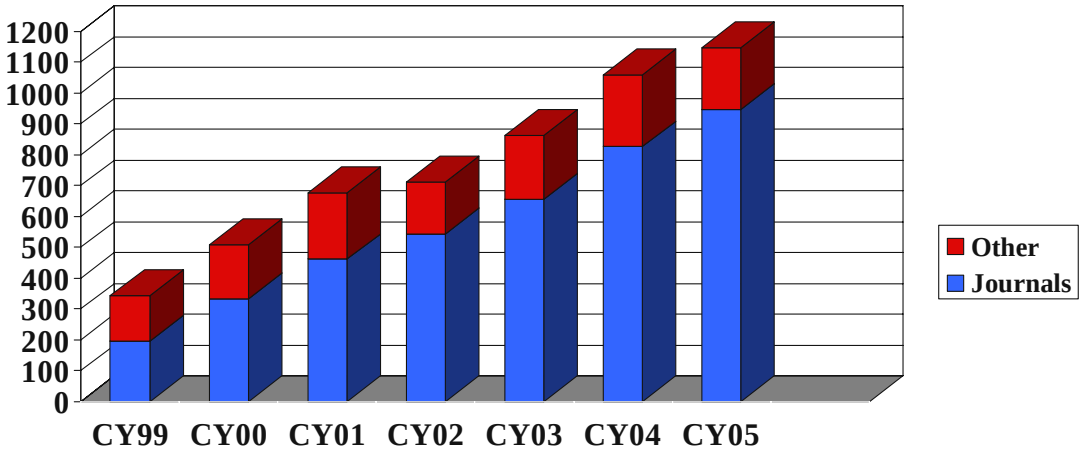


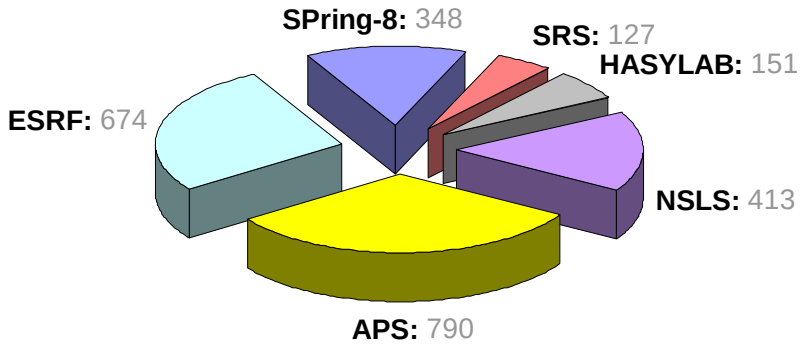

3274
visiting users
FY 2006

*Partial year

# *APS scientific impact grows….*

Refereed publications

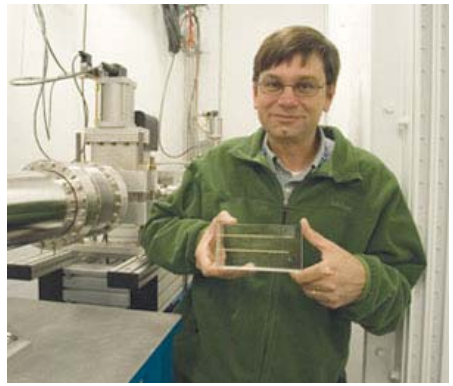



Protein structures in PDB in 2005

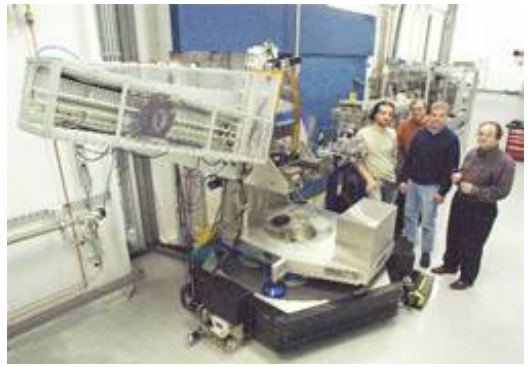
# *First light*

- **LS-CAT at sector 21: June 2006.**

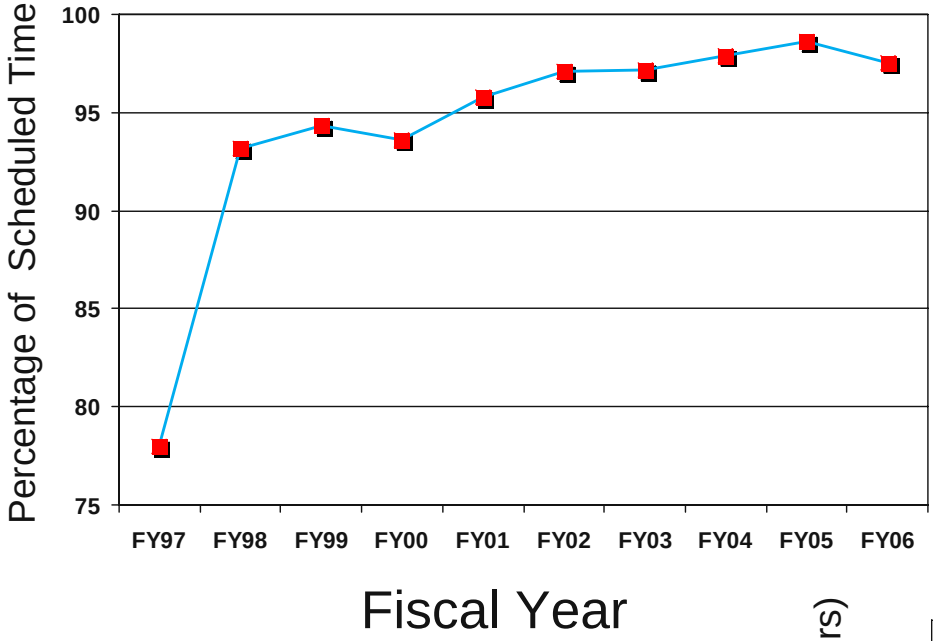


- **The High Resolution Inelastic X-ray Spectrometer (HERIX) at sector 30: October 2006**

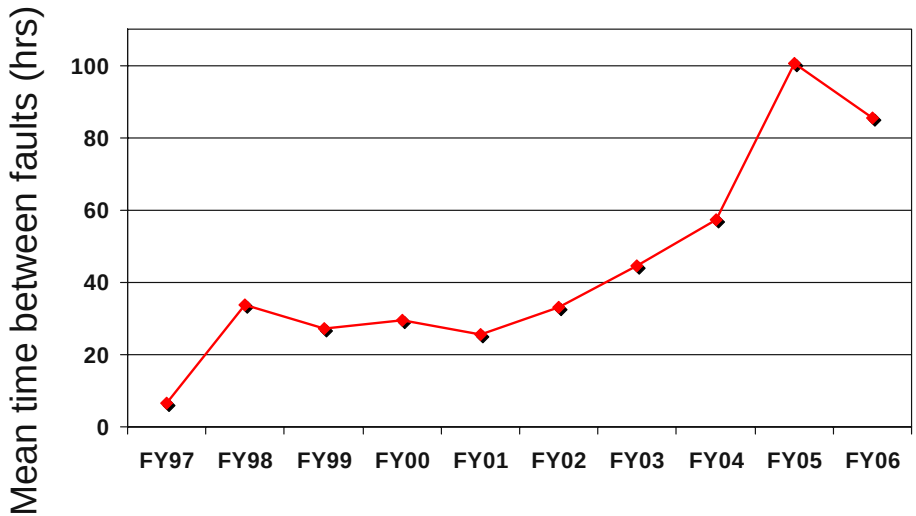
- **The Medium Resolution Inelastic X-ray Scattering Spectrometer (MERIX) at sector 30: November-December 2006**



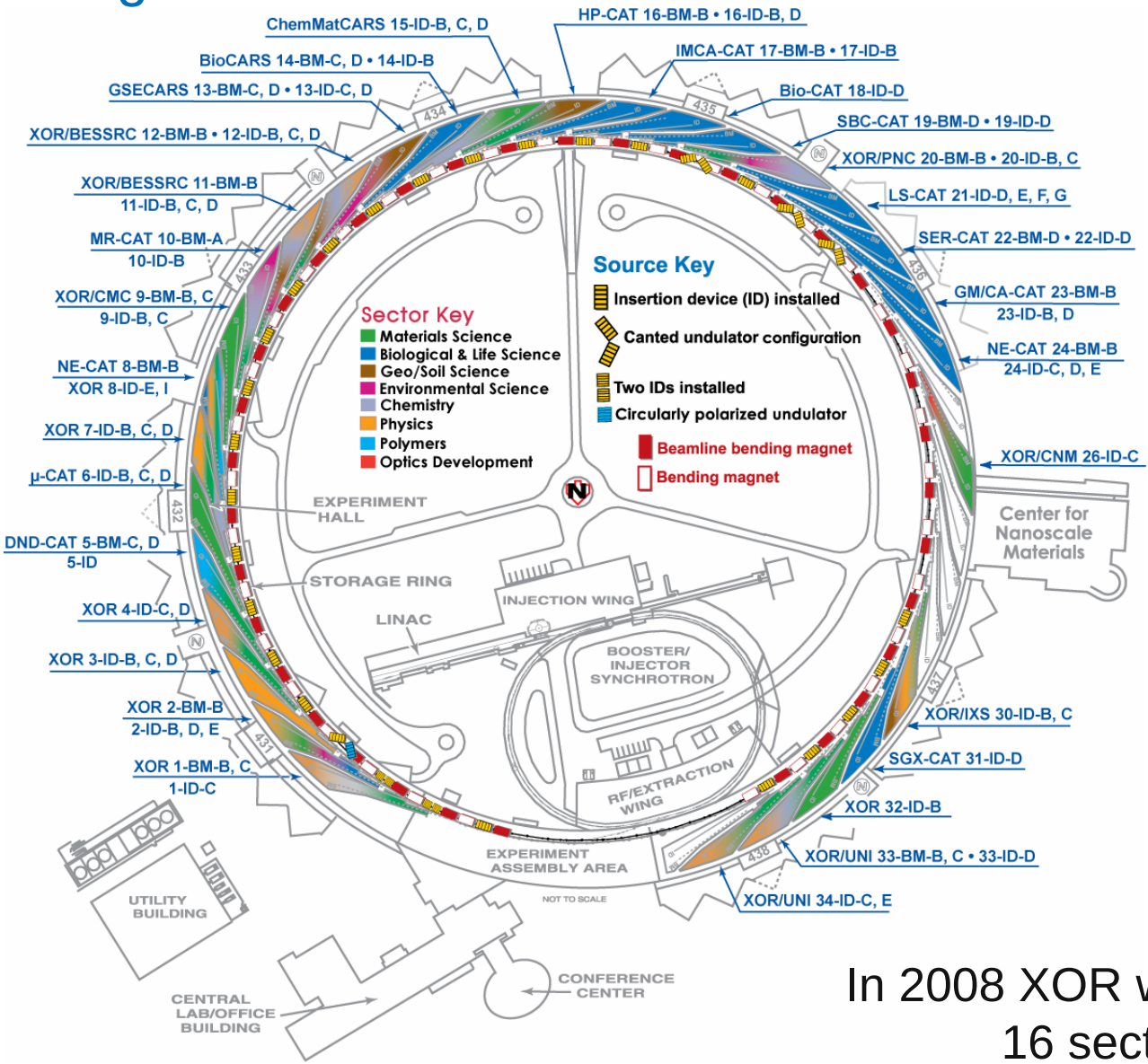
# *High APS x-ray availability…*




# *…and reliability*

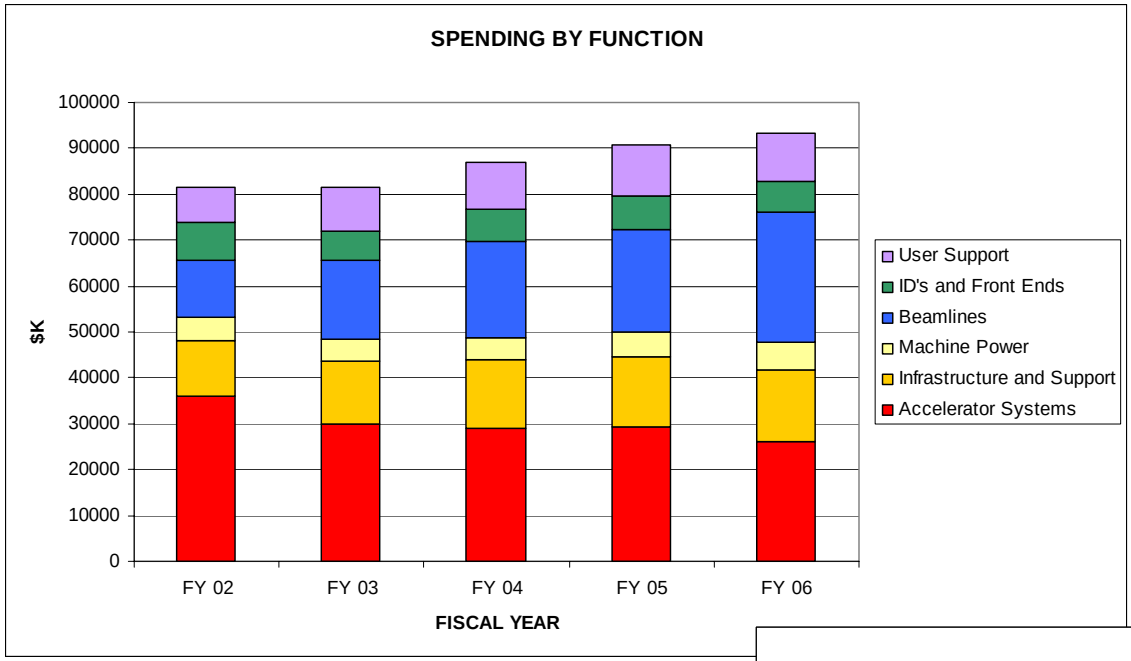


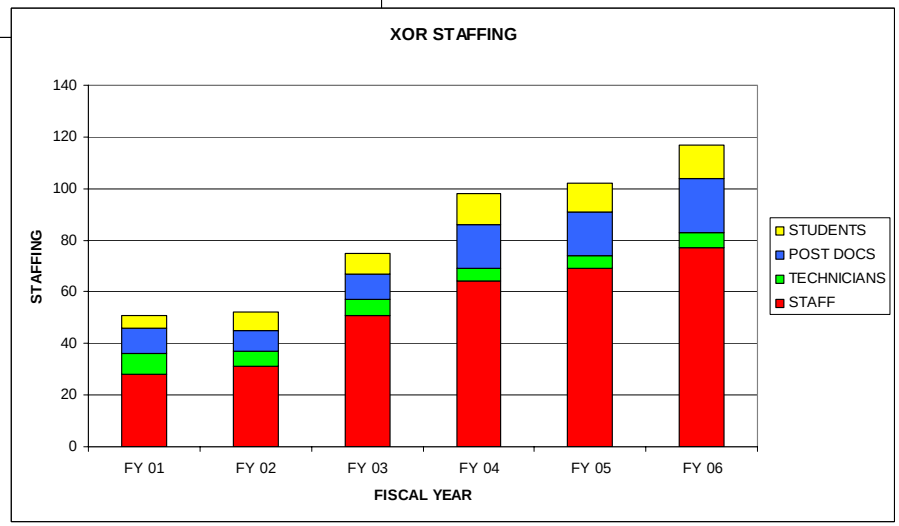
# Around the ring



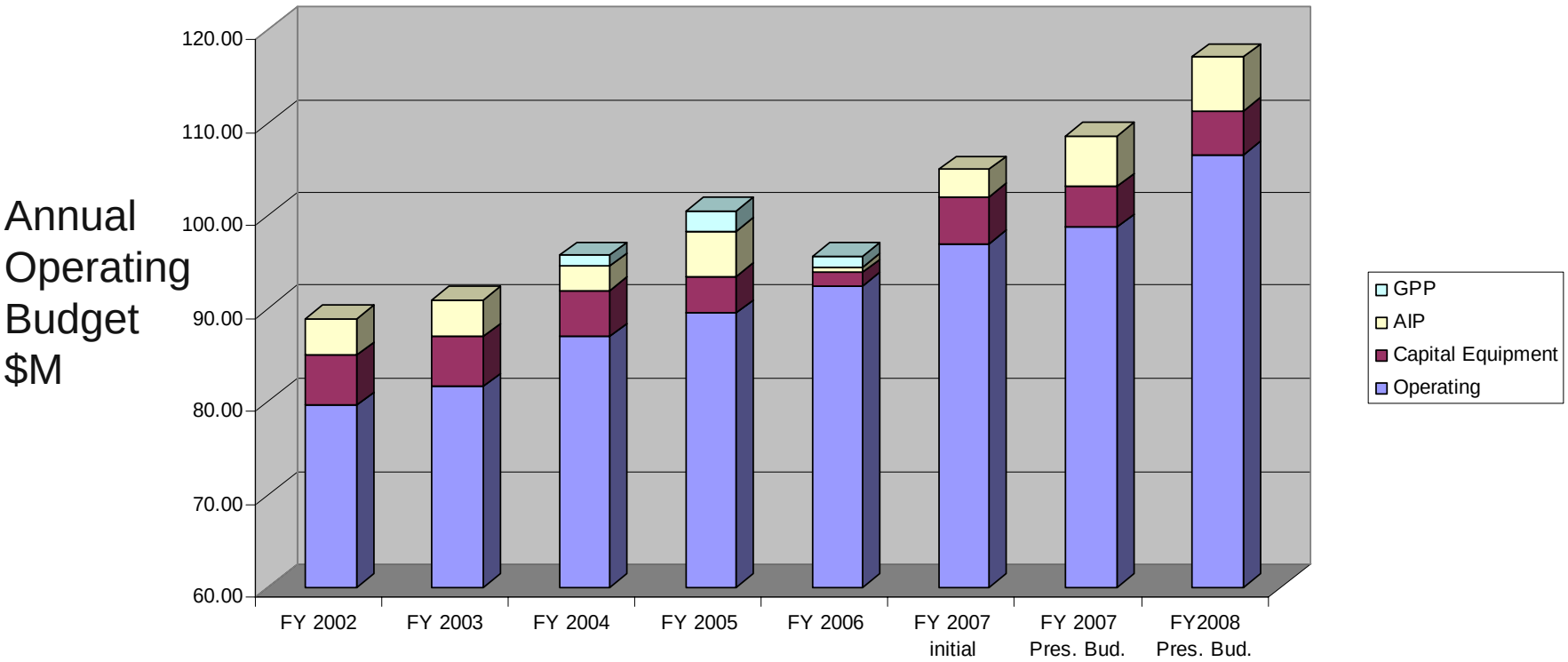

In 2008 XOR will operate 16 sectors

# APS growth drives budget increases



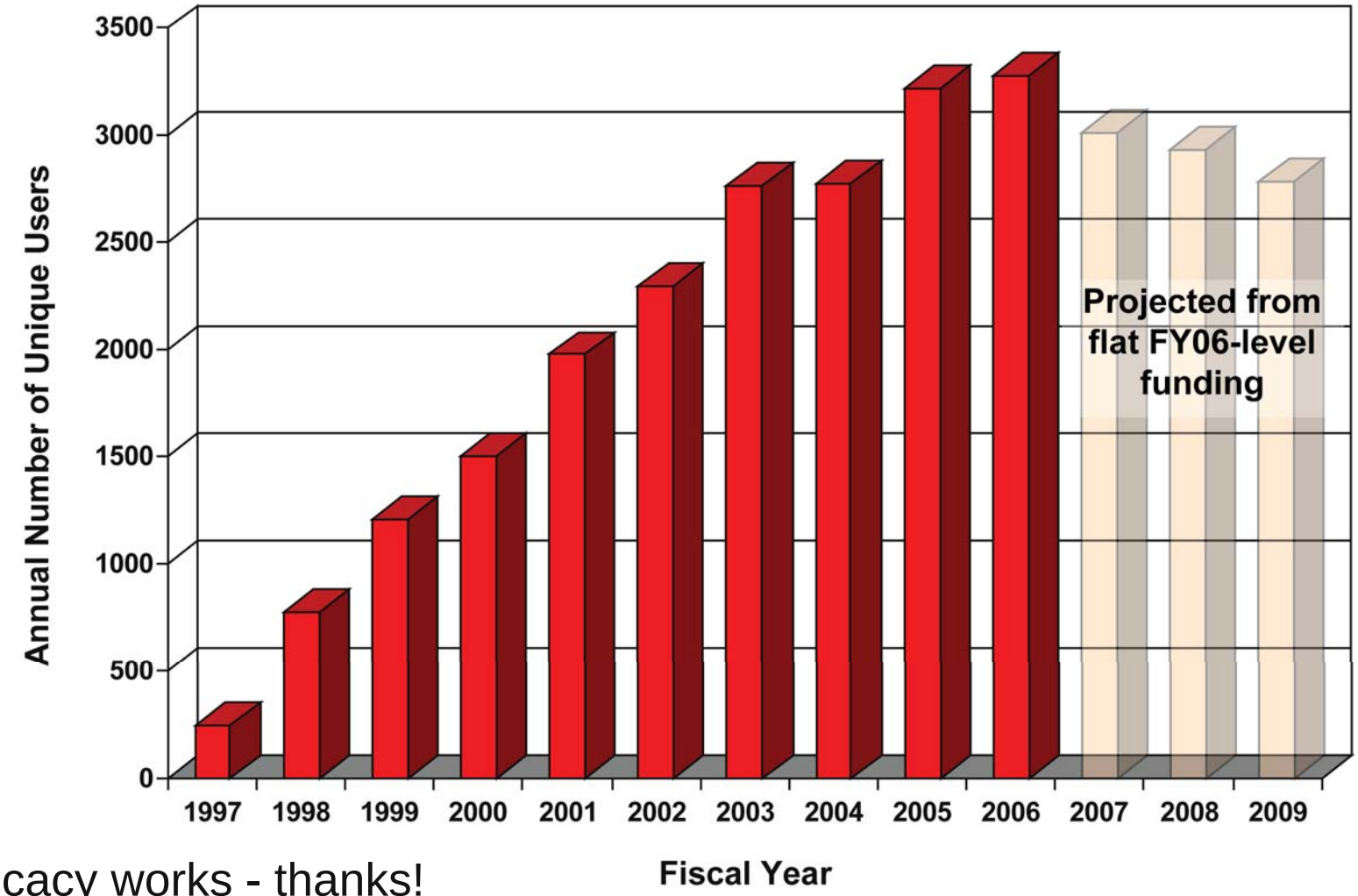
# APS budget is growing after a tough year, and a scare


**Thanks** to DOE, government and especially user support this year is much better than it could have been and next year looks even better…

We are sorry for the loss of a week in run 2007-01 due to budget uncertainty

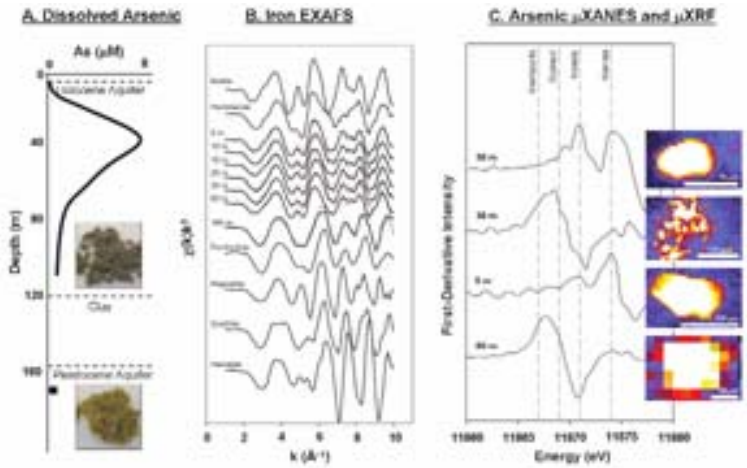
# *Congress appreciates the damaging effect of flat budgets on APS and other facilities*




Advocacy works - thanks!

# How arsenic enters a water supply

- Arsenic contamination of ground water in Bangladesh is largest environmental disaster world has seen: ~57 million inhabitants are at risk of drinking dangerous levels of arsenic from wells
- Source of arsenic understood; critical question is: How did arsenic migrate to water supply?
- Researchers using GSECARS 13-ID-C have obtained data suggesting that arsenic is released near the surface via redox cycling and is later transported to well-depth
- Researchers propose that:
  - ~15% of solid-phase arsenic is rapidly desorbed, 60% is bound in sulfides unreactive in the strongly reducing aquifer
  - Arsenic released from the surface binds weakly to silicate minerals that dominate aquifer sediments, are easily transported to well depth.
- Study indicates that remediation requires arsenic monitoring of soil environments above aquifers & developing better understanding of arsenic transport



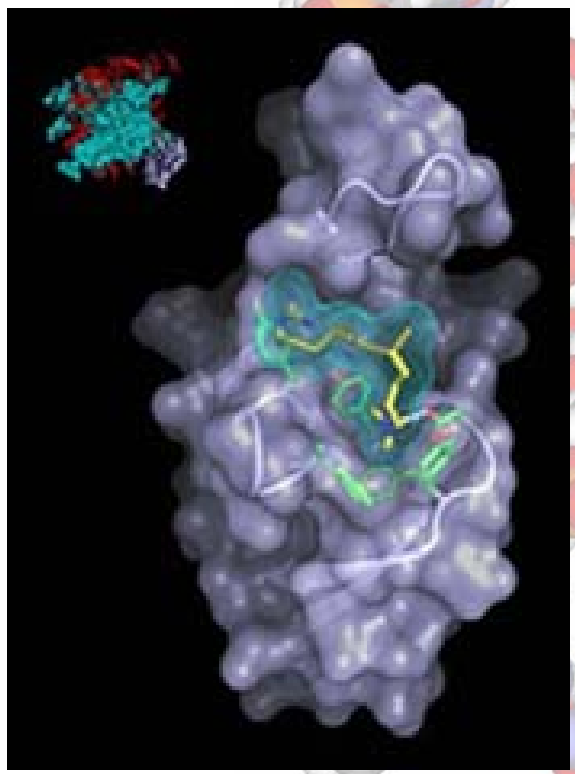

(A) Dissolved arsenic peaks at 30-40-m depth in a Holocene aquifer at the field site. They are not detected in a deeper Pleistocene aquifer. (B) Iron EXAFS linear-combination fitting of aquifer sediment samples indicate that Fe mineralogy is constant with depth within the Holocene aquifer, but Fe(III) (hydr)oxides are not detected, despite the fact that they have been suggested as a source of arsenic. (C) Arsenic is found in a host of oxidation states within the solid-phase. Arsenic-bearing sulfide minerals, a previously unrecognized source of arsenic, are found throughout the sediment profile, most commonly as 10-35-μm grains, and may account for up to 60% of the total solid-phase arsenic.



Matthew L. Polizzotto et al., Chem. Geol. 228, 97 (2006). DOI: 10.1016/j.chemgeo.2005.11.026

# *A key step in repairing DNA double-strand breaks*

- Double-strand breaks in DNA can result from external agents such as UV radiation or mutagenic chemicals
- Unrepaired, a single DNA double-strand break can lead to cell death or cancer
- So cells have evolved elaborate machinery made of proteins to detect, repair DNA lesions
- Atomic-level understanding of how this DNA repair machinery functions is important for correcting malfunctioning DNA double-strand break repair process
- Mayo research team using SBC-CAT 19-ID showed that a human protein essential for repairing DNA double-strand breaks is recruited to the sites of DNA damage by direct interaction with histone H4, a protein constituent of the DNA packaging structure called chromatin



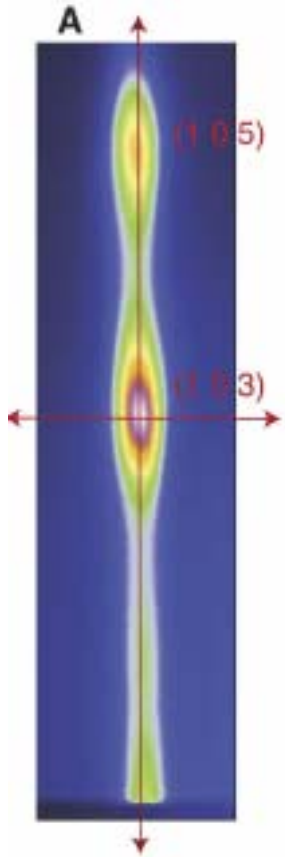
**The atomic structure of the protein 53BP1 identified by Mayo researchers. (Courtesy: Mayo Clinic)**



Maria Victoria Botuyan et al., Cell **127**, 1361 (29 December 2006).

# An insulating breakthrough

- A new insulating material with the lowest thermal conductivity ever measured for a fully dense solid has been created at the University of Oregon and tested at XOR/UNI 33-BM
- While not having immediate application, the principles involved could lead to improved insulation for a wide variety of uses
- Used a novel approach to synthesize various thicknesses of tungsten diselenide, yielded a random stacking of tungsten-diselenide planes ($WSe_2$ ), possibly leading to a localization of lattice vibrations
- Resulting synthesized material yielded thermal conductivity 30 times smaller than that for single-crystal $WSe_2$ and factor of six smaller that minimum level predicted by theoretical computations for the cross-plane thin films used in the experiments



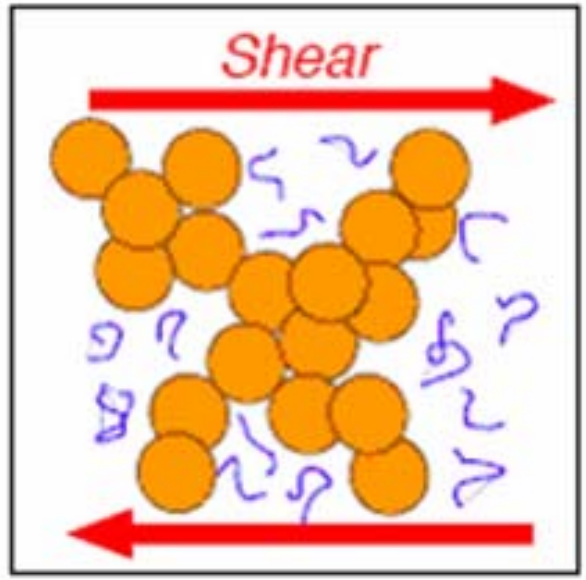

False-color depiction of the x-ray diffraction intensities for a 32.5 nm thick $WSe_2$ film collected at 33-BM using 18.5 keV photons collected by the area detector in the vicinity of the (1 0 3) and (1 0 5) reflections. The vertical direction is normal to the sample surface and the horizontal direction is in the plane of the sample



Catalin Chiritescu et al., Science **315**, 342 (Jasnuary 2007). DOI: 10.1126/science.1138067

# *Watching gels get the stress out*

- Macroscopic flow properties of a wide assortment of disordered soft materials (foams, concentrated emulsions, colloidal suspensions) can change dramatically from fluid-like to solid-like with subtle changes in microscopic characteristics
- This behavior bears strong resemblance to liquid-glass transition in molecular fluids
- Microscopic mechanisms of recovery from shear in disordered soft solid materials studied and compared to aging in glasses viaUniversity of Illinois, and Florida State University have combined
- Multispeckle x-ray photon correlation spectroscopy at XOR and diffusing wave spectroscopy studies on concentrated colloidal gels subjected to strong shear combined
- Studies call into question connection between aging in glasses and slow equilibration that various disordered soft solids display
- Should motivate a rethinking of models that seek to unify these phenomena



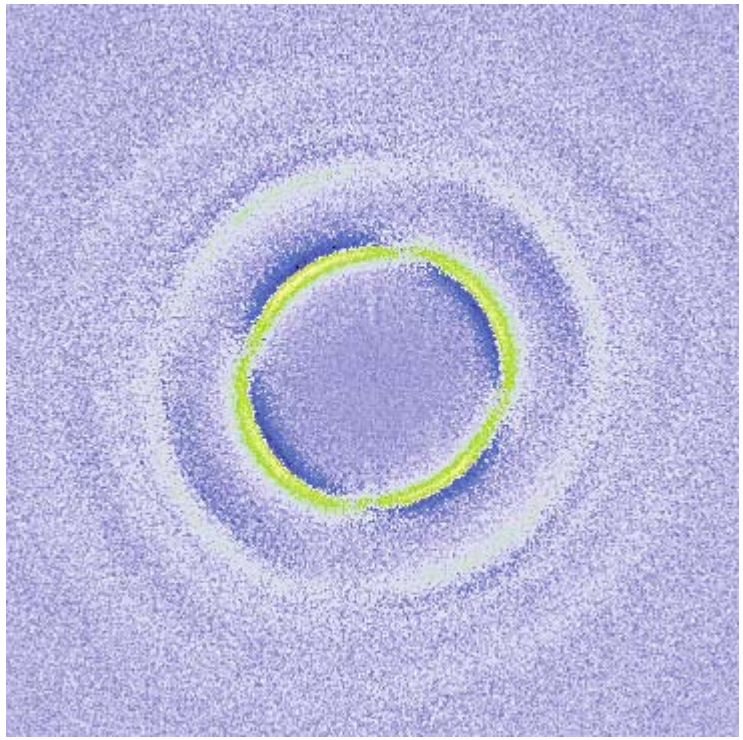

Cartoon of gels under shear



B. Chung et al., “Microscopic Dynamics of Recovery in Sheared Depletion Gels”, Phys. Rev. Lett. **96**, 228301 (2006).

# *Looking into metallic glass*

- **Metallic glass is an amorphous metal that does not crystallize when cooled from liquid to solid**
- **Atomic-scale structure is highly disordered, much like a liquid, gives metallic glasses unique properties of high strength and elasticity that make them ideal for a wide range of applications, incl. military hardware, spacecraft, sporting equipment**
- **The ability to measure elastic strain in glasses thought to be limited by material's structural randomness, difficulties in collecting and analyzing data**
- **Researchers used XOR 1-ID to measure elastic strain on a bulk amorphous metallic alloy**
- **Study shows that elastic strain in metallic glass can be measured accurately with high-energy x-ray scattering**



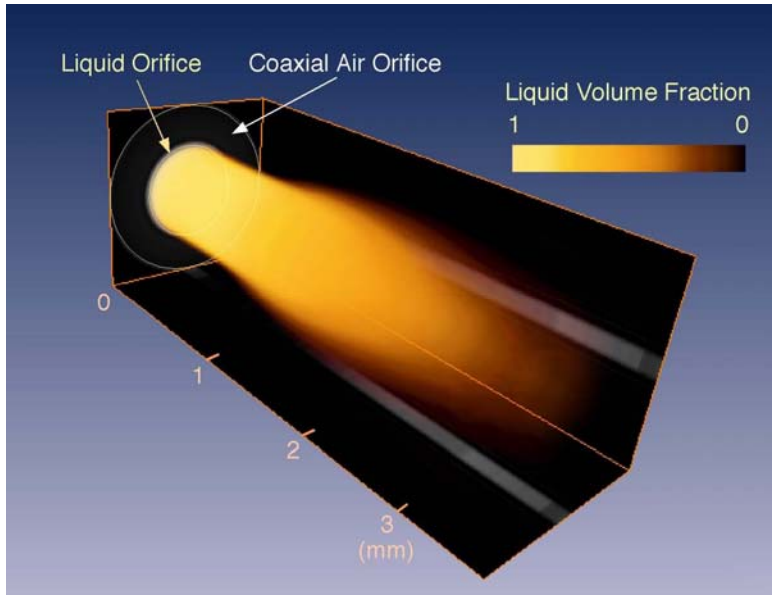
Change in x-ray scattering between loading and unloading for a specimen tested in pure shear. The distortion of the scattering rings reflects the principal strains (which are oriented approximately ± 45°from vertical)



T.C. Hufnagel et al., Phys. Rev. B 73, 064204 (2006). DOI: 10.1103/PhysRevB.73.064204

# *Beneath the surface of high-speed industrial sprays*

- "Seeing" beneath the surface of a jet from ubiquitous high-speed industrial paint sprayer can yield important new information needed to optimize the sprayers themselves
- Researchers and engineers from Argonne and Illinois Tool Works (ITW), Inc. (Glenview, IL) using XOR 7-ID beamline have captured first images of complex and transient multiphase spray flow just millimeters from a high-speed industrial spray nozzle
- First-ever visualization of near-nozzle high-speed coaxial flows can be used to develop and validate liquid breakup models and is indispensable for understanding downstream spray formation

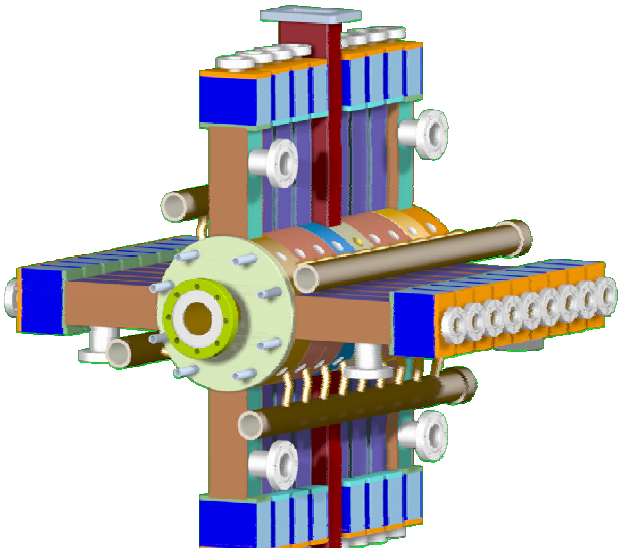


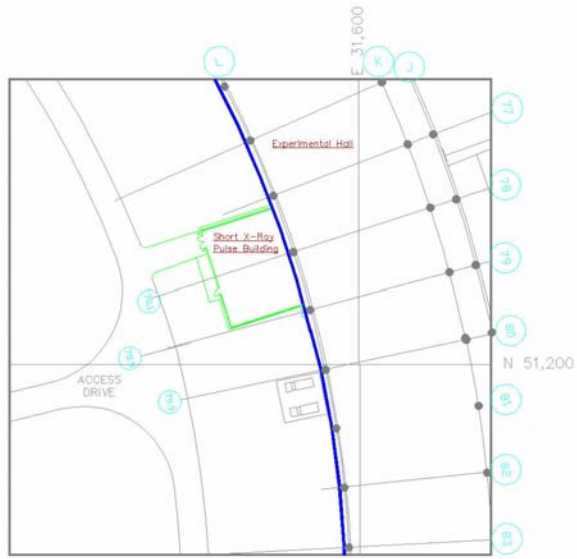

Three-dimensional rendering of air-assisted coaxial spray in near-nozzle region with an air pressure of 137 kPa (corresponding to a Weber number of 380). False color intensity represents liquid volume fraction, which was quantified for first time with the x-ray phase-contrast imaging.

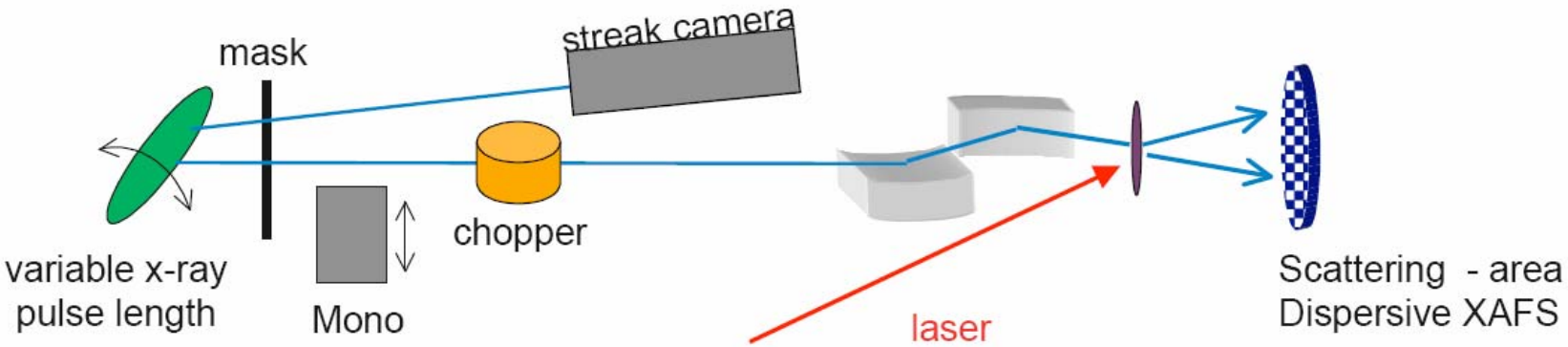


Y. J. Wang et al., "Quantitative x-ray phase-contrast imaging of air-assisted water sprays with high Weber numbers," Appl. Phys. Lett. **89**, 151913 (9 October 2006).

# Short pulses at APS
## A million photons in a trillionth of a second at sector 7 in 2008






CHEAP
CHIRP
SHACK

# When things get tough – call MOM!



Mechanical Operations and Maintenance Group

Argonne NATIONAL LABORATORY

Advanced Photon Source
APS Engineering Support Division (AES)

About AES | AES Groups | Operations & Safety | APS Resources | Facility | Search APS...

Argonne Home > Advanced Photon Source >

- Contacts
- Groups
- Goals
- Job Postings
- Mission
- Operations & Statistics
- Organization Chart
- Seminars

Site Map

## APS Engineering Support Division (AES)

The APS Engineering Support Division provides reliable operations and technical support to the Advanced Photon Source user community.

AES works to ensure that the Advanced Photon Source maintains its status as a preeminent scientific user facility.

**Featured AES Group Links**

- Building and Services FAQ
- Integrated Content Management System (ICMS)
- IT Computing Policies
- IT Support Request
- MOM Request for Service
- Shutdown Planning Wiki

**Related APS Links**

- APS Intranet
- CAT Chat Minutes
- Email Portal (Calypso)
- Operations Logbook
- Project Management Process
- Resources and Information
- Safety and Training

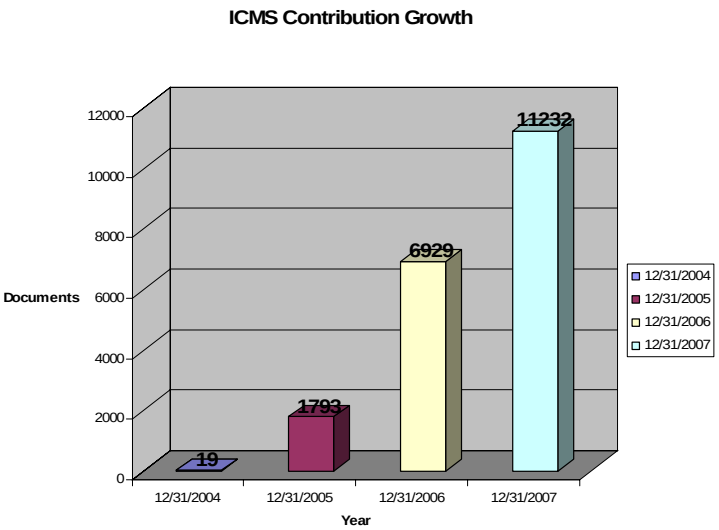
**What's New**

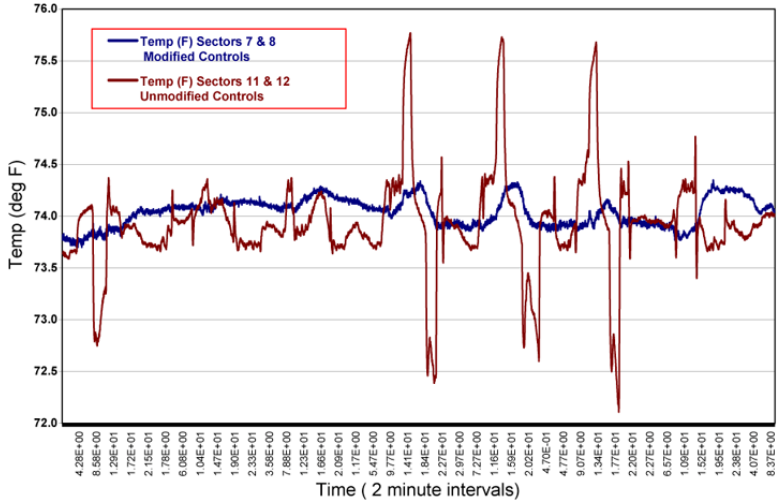
The Center for Nanoscale Materials (CNM) is complete! The CNM is a two-story, 85,000 square foot structure adjoining the west side of the APS.

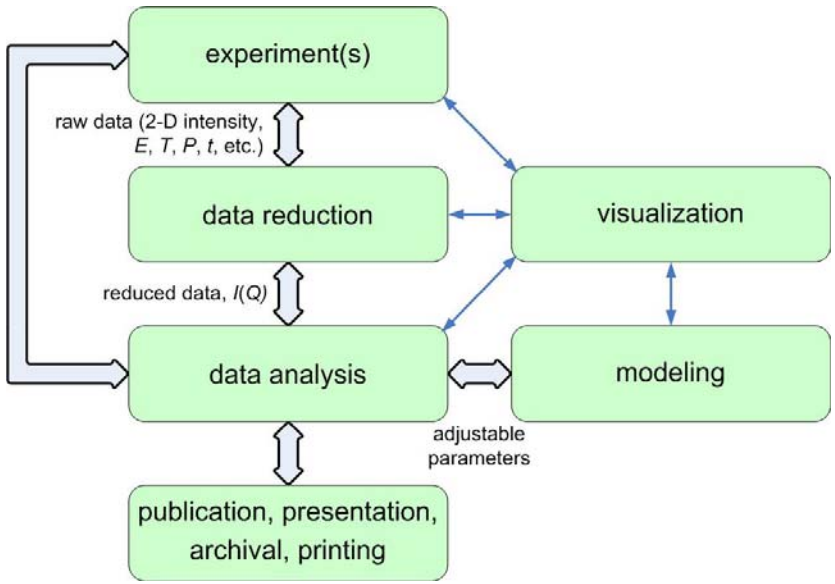
The new facility includes clean rooms, specialized research laboratories, offices and meeting spaces to accommodate users, scientific and technical staff and administrative support.

Click on MOM Service

# Behind-the-scenes engineering innovations…



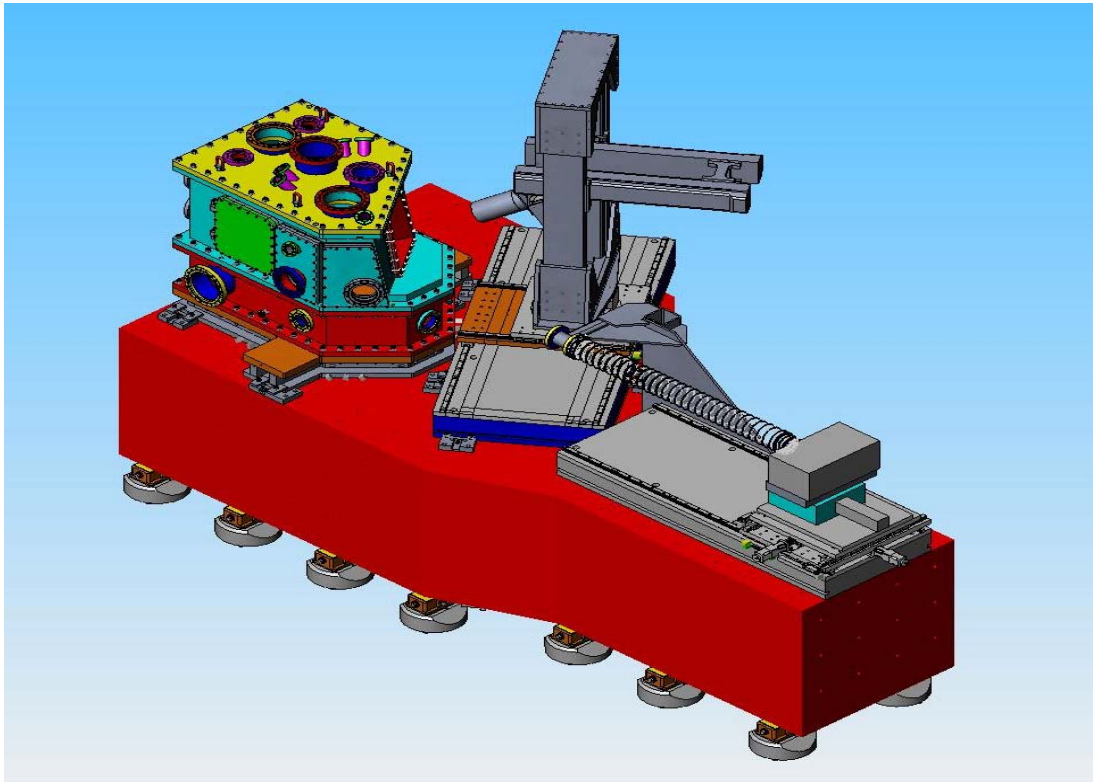



# *The Linac Coherent Light Source (at ANL)*


- A matrixed partnership - Stanford Linear Accelerator Center and ANL are building the world's first x-ray free electron laser
  - ANL experts design and produce 130 meters of undulator systems (33+ spares) for installation in new underground tunnel at SLAC
  - ANL (APS) undulator system TPC ~$45M
  - FY 06 & 07 - Undulator system construction
  - FY 08 - Installation, commissioning, and 1st light

# *Center for Nanoscale Materials (CNM)*

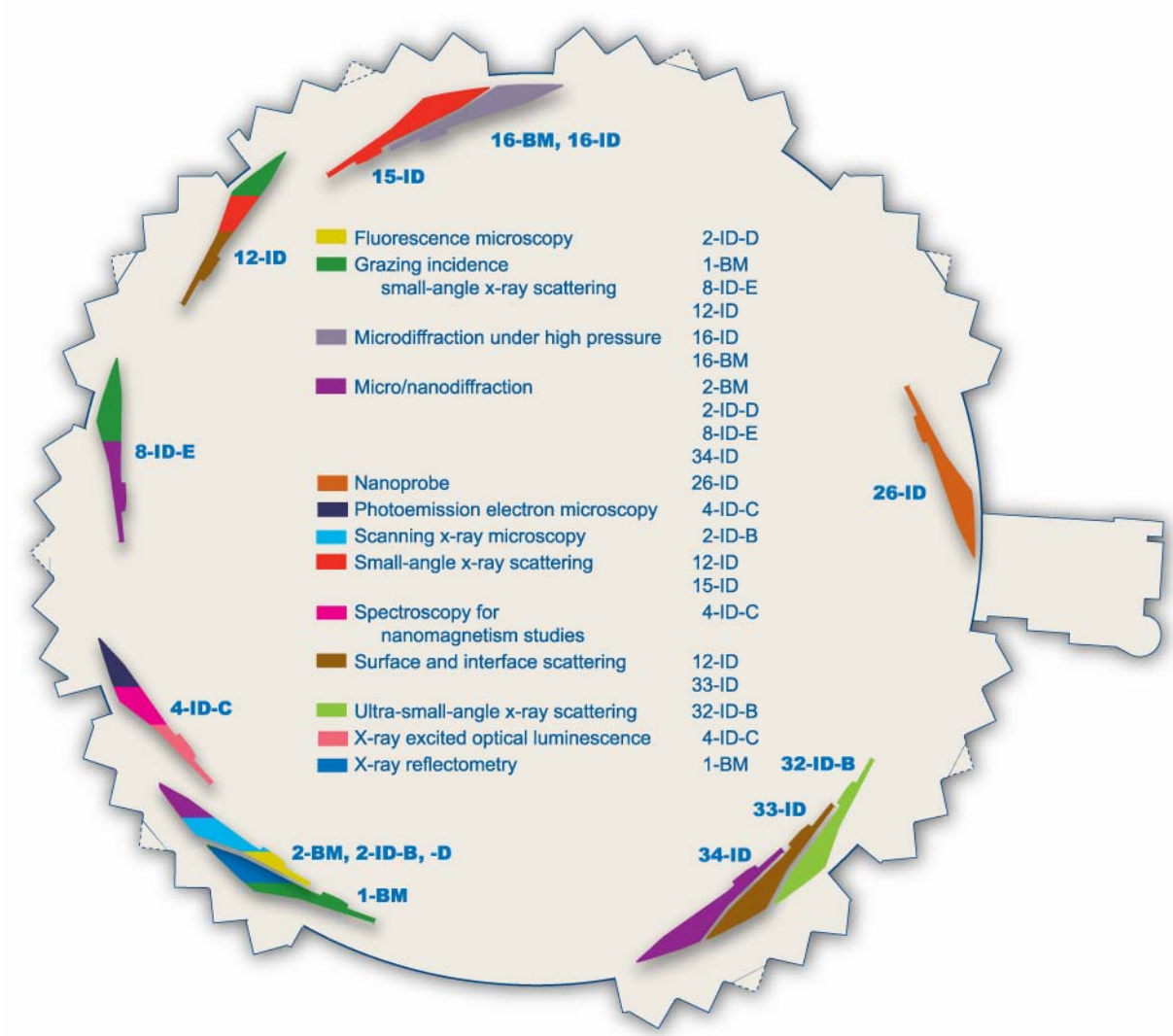
Partnership



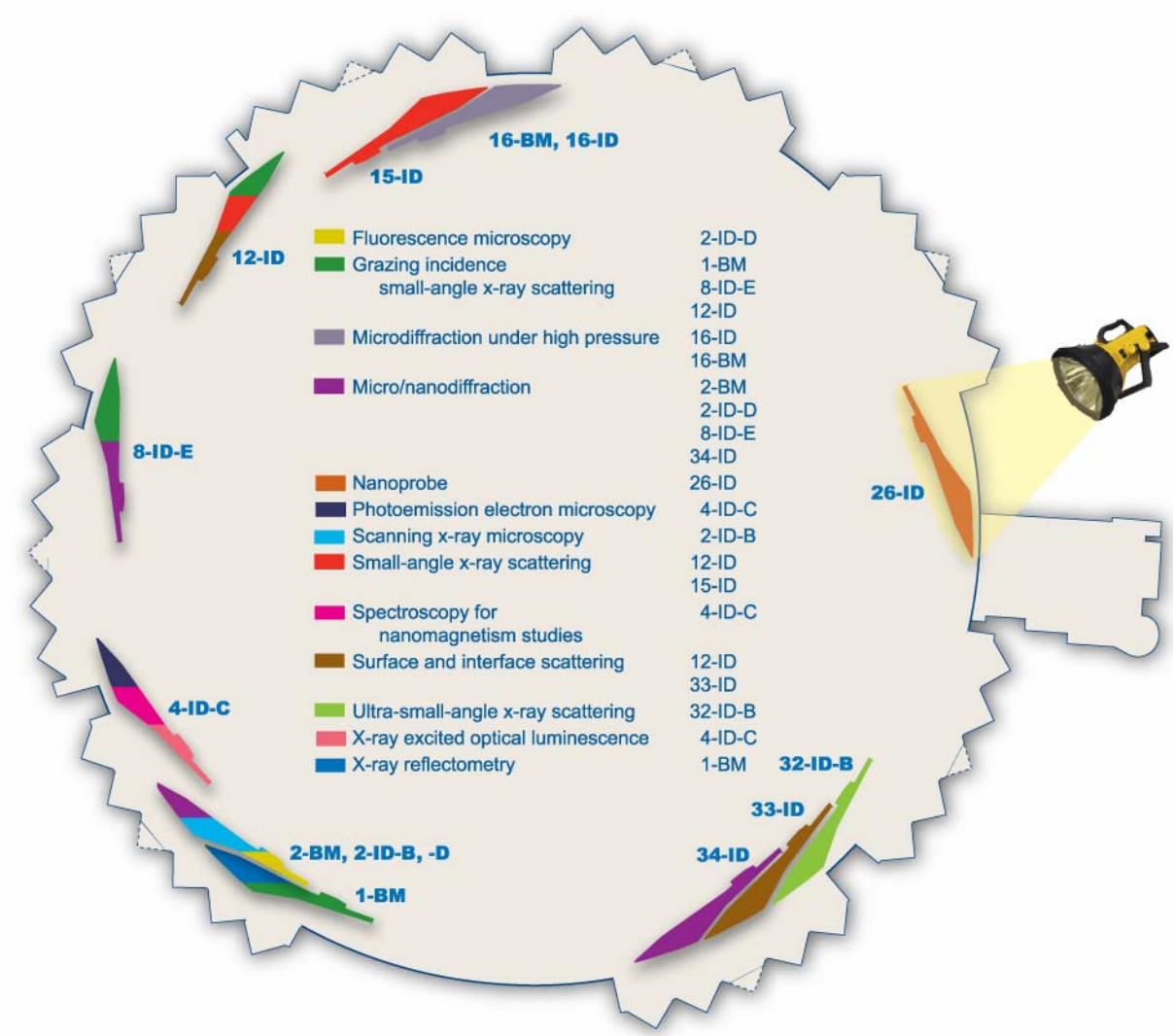
Nanoprobe finishing construction at 26-ID will be jointly operated by CNM and APS

Aiming for a 10-nm-resolution x-ray microscope

# APS science at the nanoscale

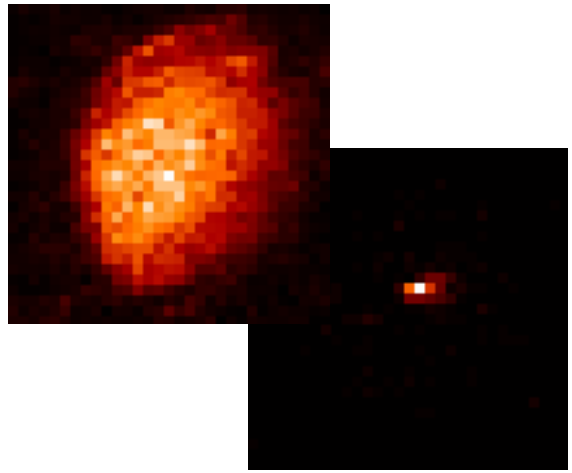


# APS science at the nanoscale



# *Future upgrade to the APS?*

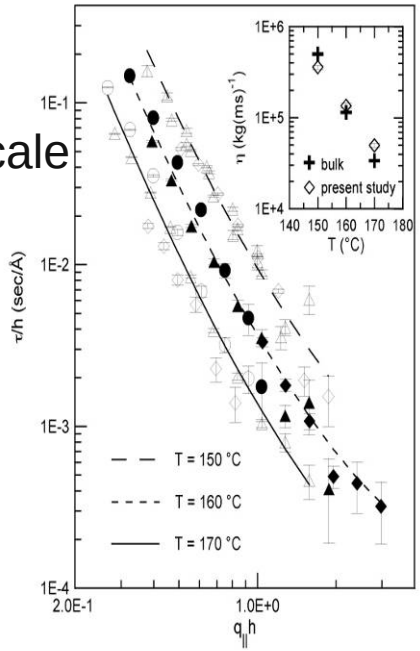
110 years



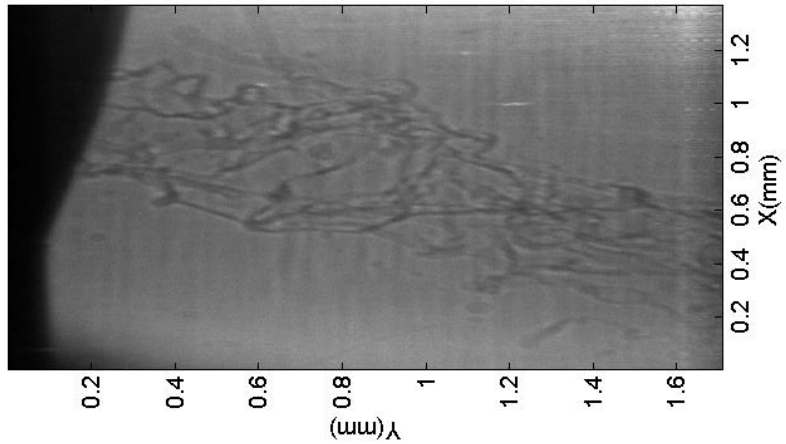
- Imaging is back at the forefront of x-ray science
- Next-generation sources offer full coherence, which will revolutionize x-ray imaging
  - And short pulses for study of ultrafast phenomena
- We are exploring the possibility of upgrading the APS to the fourth generation
  - Most promising option at this point appears to be an energy recovery linac (ERL)

# *Limits of speed and sensitivity explored today at APS*

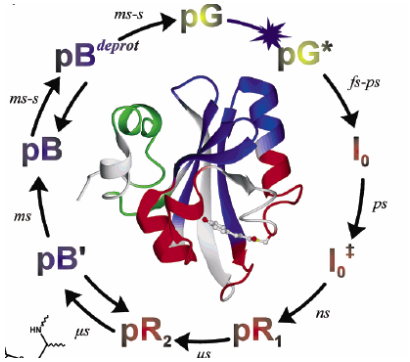
Capillary waves on nanoscale polymers



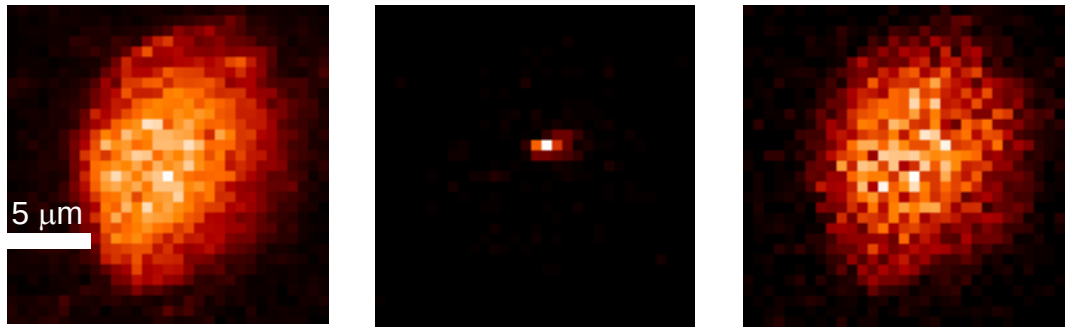

100-ps shots of fuel spray



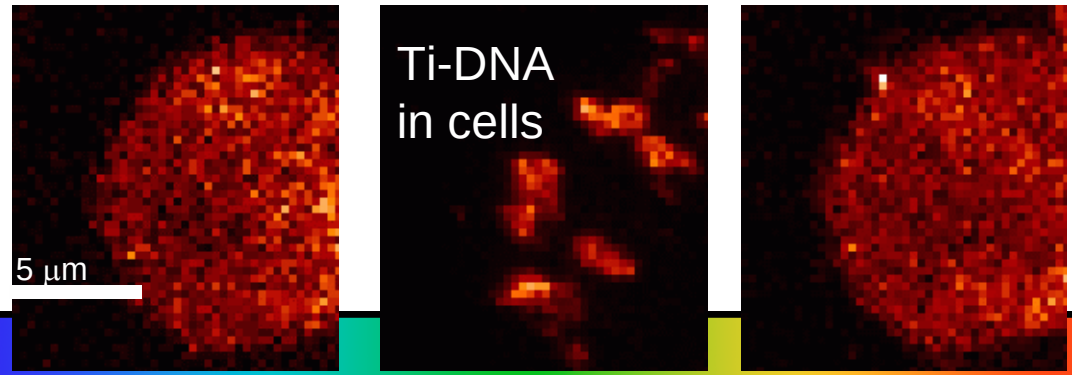

Yellow-photoactive protein




**A:** P: 13 - 0 | Ti: 0.25 – 0.00 | Zn: 0.039 – 0.001



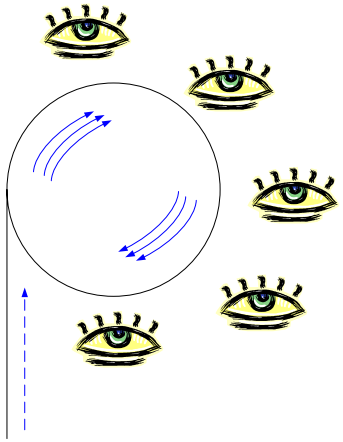

**B:** P: 0.4 - 0.0 | Ti: 0.22 – 0.00 | Zn: 0.007 – 0.000



# What is the fourth-generation revolution in x-ray sources?

$\tau_{lifetime} >> \tau_{relaxation}$

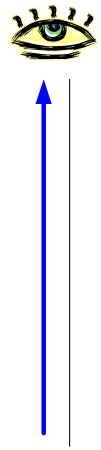
## Storage ring



- Many users
- High flux
- Low brilliance
- Long pulses

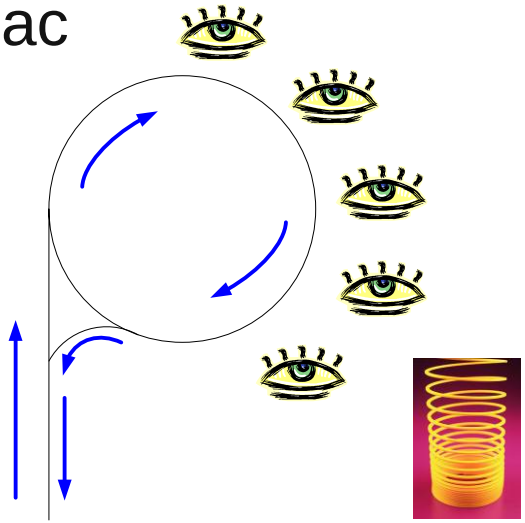
$\tau_{lifetime} << \tau_{relaxation}$

## linac source (=> FEL)



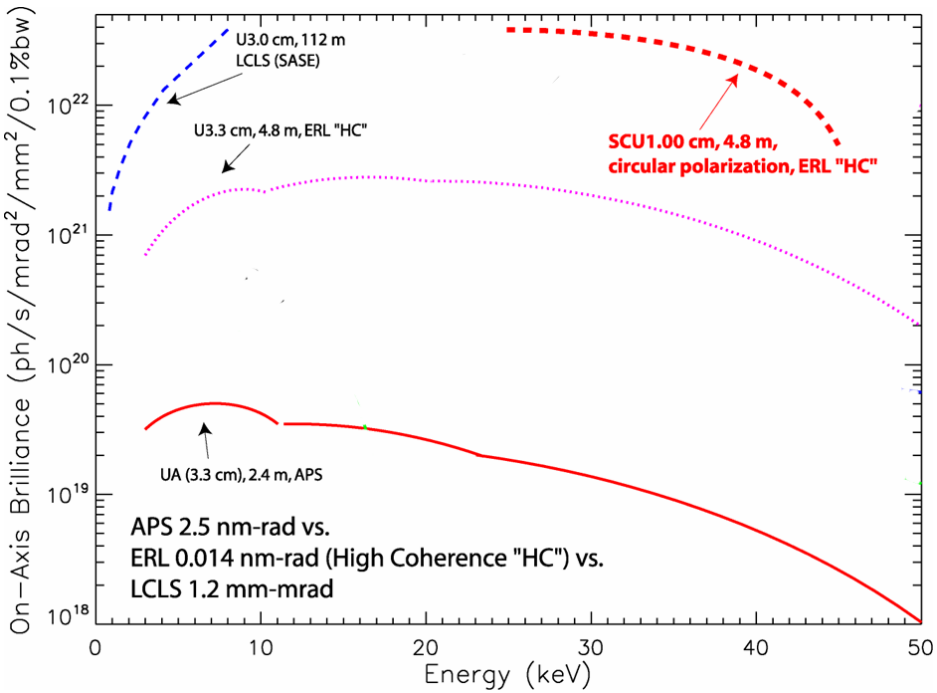
- Extremely high peak brilliance
- Full spatial coherence
- Ultrashort pulses
- Temporal coherence?
- Low rep rate
- Fewer users

## Energy-Recovery linac



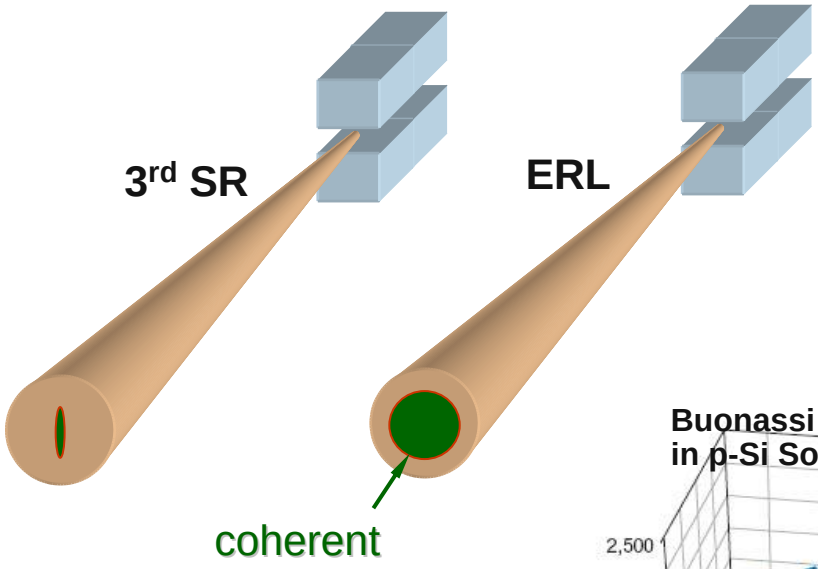
- High average brilliance
- Full spatial coherence
- Many users
- High flux
- Short pulses but closely spaced and lower # of photons per pulse

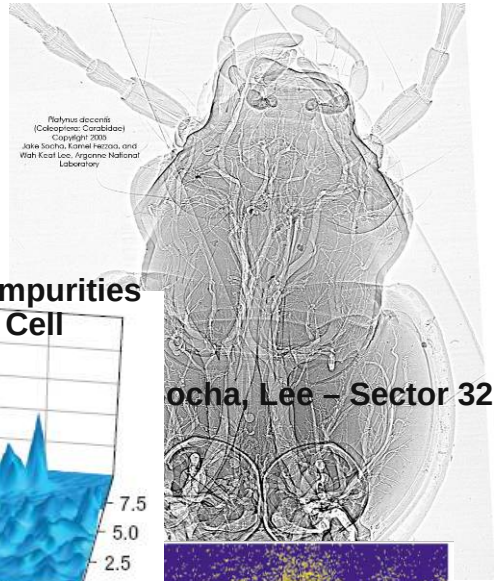
# What would an ERL offer?




- Substantially spatially-coherent source (“like a laser”)
  - It can put >100 times more flux into a <10-nm probe and improve phase contrast compared with a storage ring
  - And deliver to many users
- It offers pulses 100 times shorter or less (in the sub-ps regime)
  - Does not rival FEL for peak brilliance
  - But compatible with FEL upgrade as well
- Natural upgrade path for storage ring such as APS
  - Could be done without compromise or major disruption

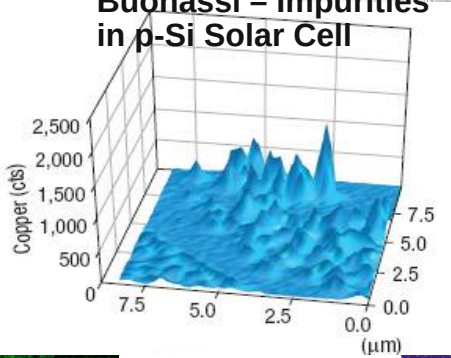
# ERL: Ideal source for imaging and nanoprobes

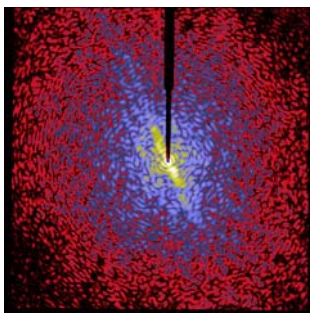


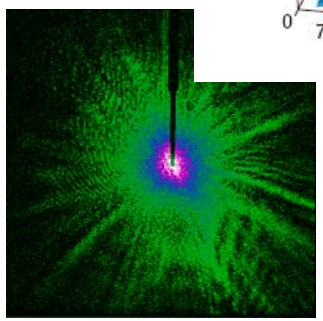




ocha, Lee – Sector 32

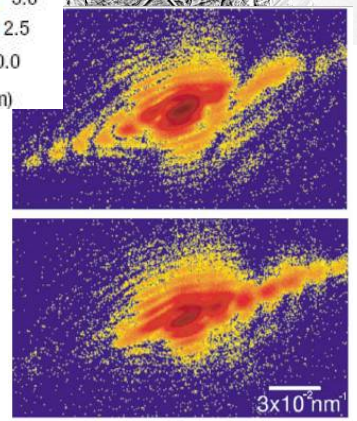
Buonassi – Impurities in p-Si Solar Cell





Miao – actin filaments, 2-ID-B

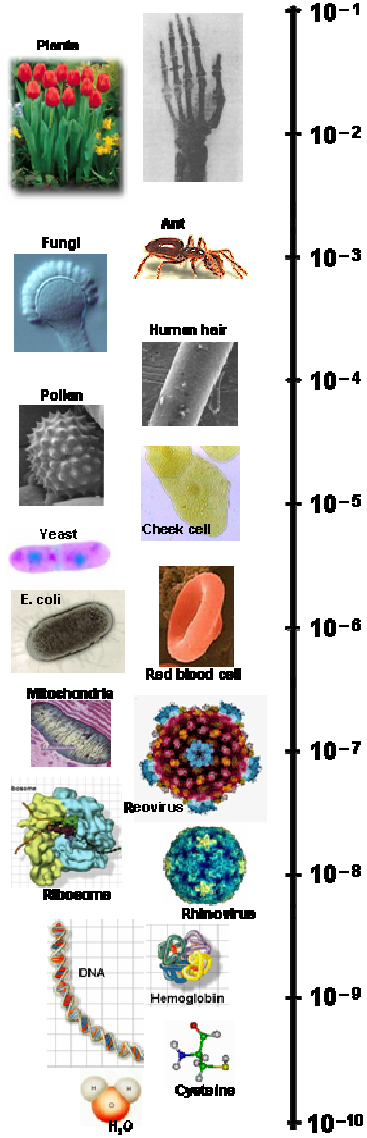



Robinson – Au particles 34-ID-C

Imaging

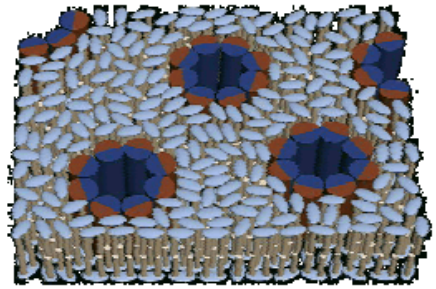
Scattering

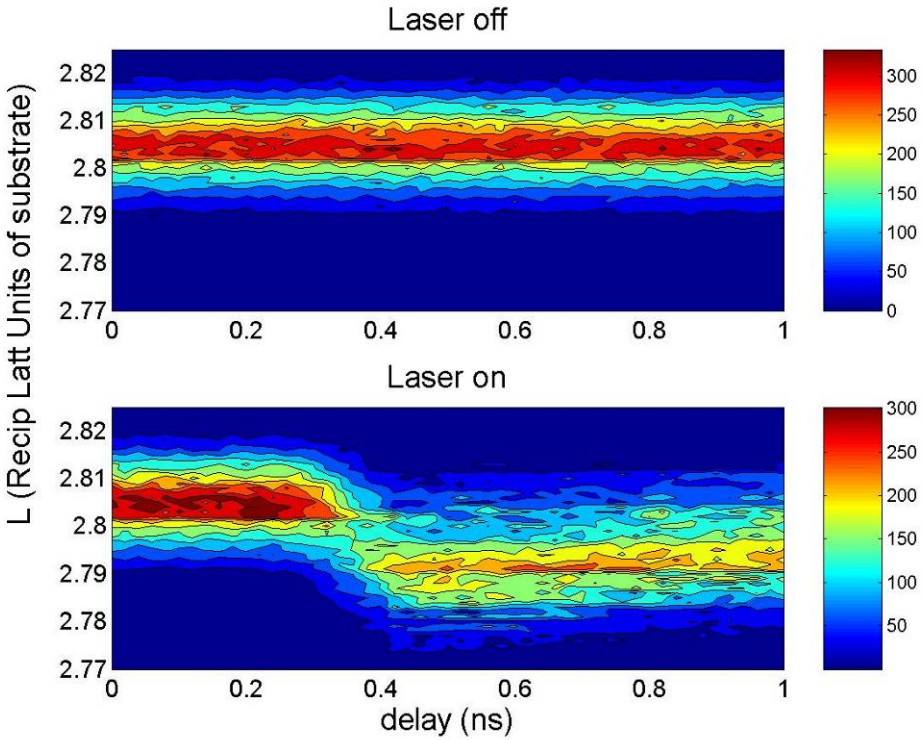
Size (m)

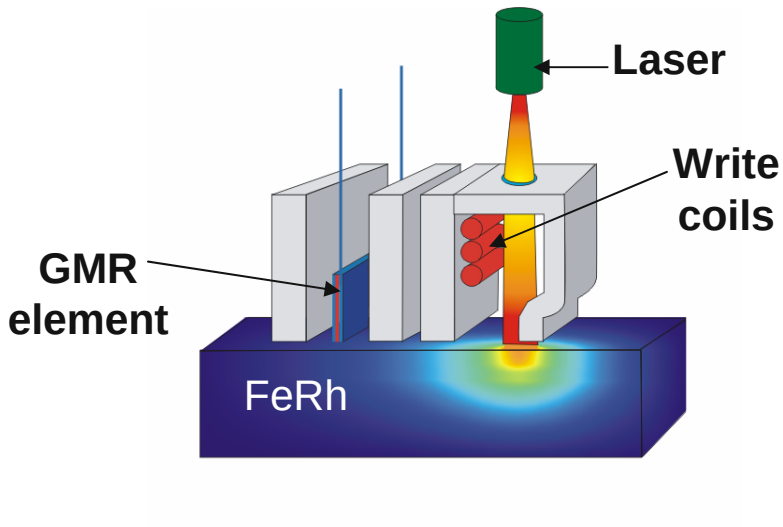


# *And the ERL would revolutionize time-resolved studies*

- Will allow studies of nanoscale dynamics 10,000 times faster (sector 8)
- Will access the time scale of a picosecond and below for ultrafast science *(fast-track ps pulses at sector 7)*

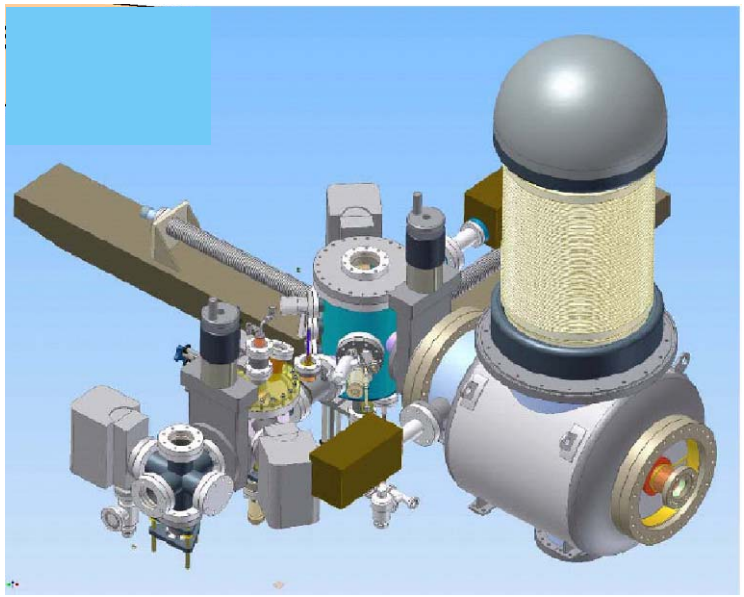




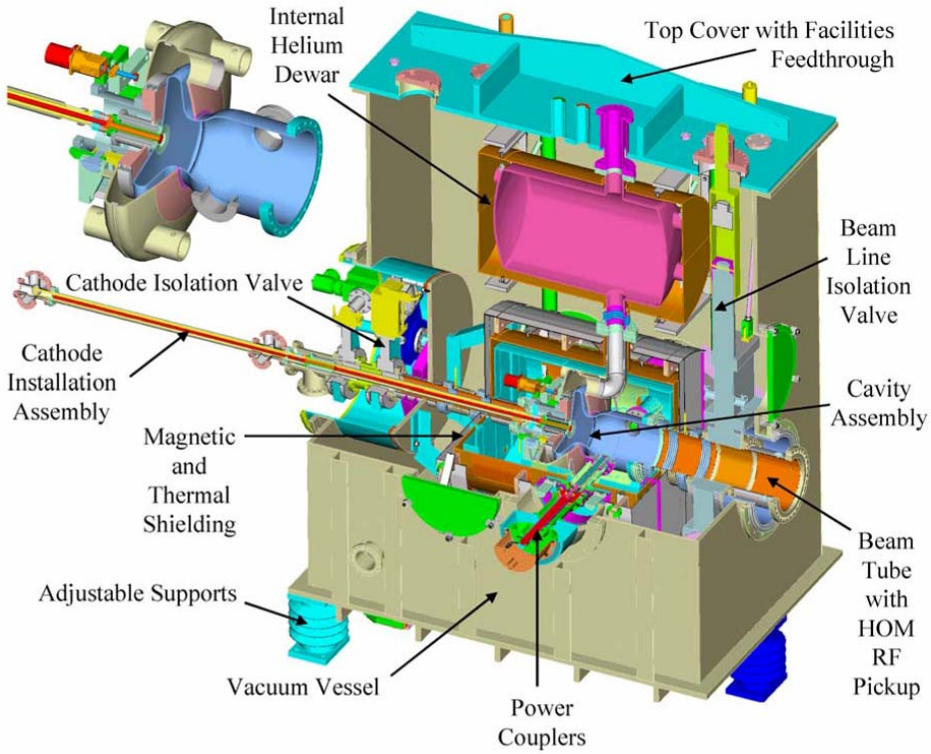



# Serious R&D required

***Cornell dc gun***



***BNL – AES SRF gun***




Major R&D challenges on superconducting rf and especially crucial electron *gun development* – collaborations around the world

Supported by ANL Accelerator Institute and laboratory strategic initiative

# *The future is coming into focus…*

- APS is the largest user facility in U.S. and growing in scientific impact
- We are developing existing and new sectors and capabilities
- We are exploring options for an upgrade to APS in the next decade, and favor an ERL at this point
- We will continue to explore the scientific case for an upgrade, and technical options with our user community

Sam Krinsky (NSLS) Klaus Balewski (DESY) Annick Ropert (ESRF) Vic Suller (Chair) (CAMD) Georg Hoffstaetter (Cornell U.) Andrew Hutton (JLab) Elaine Seddon (Daresbury) Max Cornacchia (SLAC, retired)
Not pictured: John Galayda (SLAC)

Advanced Photon Source Machine Advisory Committee
Argonne National Laboratory
November 15-16, 2006